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Review Article

BIOPLASTIC WORLD: A REVIEW

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ABSTRACT

Recently plastic disposal has emerged as a persistent and potential environmental problem in the world. The improper disposal of the plastics has resulted in the death of millions of animals and reduction in the fertility status of the soil by dumping plastic waste on both land and sea. The environmental concern has increased on the plastic waste pollution, which has resulted into a rapid development in the environmental friendly product. Bio plastics are one of the most innovative environmental friendly materials having advantage of lower carbon footprint. The Bioplastics like PHA (Polyhydroxyalkanoates), PLA (Polylacticacid), PHB (Polyhydroxybutyrates) are manufactured which are biodegradable with similar functionality like that of conventional plastics and has the potential to reduce the dependence on petro-plastic that could be an environmental hazard. The present review will highlight some aspects of bio plastics, its production, application, recycling, and recent development in bio plastic. Every country desperately needs to develop bio plastic usage and its proper waste management for a pollution free world.

Keywords: Bio plastic, Carbon footprint, Polyhydroxyalkanoates, Polyhydroxybutyrates, Polylacticacid

1. INTRODUCTION

Chemically manipulated conventional plastics are long chain synthetic polymer; their structure is made up of number of shapes and different strength to obtain high molecular weight and long durable substances [1]. It is made to be utilized by manufacturing industries ranging from medicine to automobiles [2].

The Bakelite was first synthetic material produced in Belgium, 1907 and there are now 20 different groups of plastics, whose worldwide usage is in the order of 245 million tons for the year 2006. A wide range of application results to annual plastic production to surpass 300 million tons by 2015 world widely [3]. The continued use will accelerate the rates which are unsustainable and will cause a significant burden for future generations. These plastic residues in landfills degrade very slowly, which can cause the original products to remain in our landfills for hundreds or even thousands of years. This accumulation of plastic waste has become a major concern in terms of the environmental pollution [4]. The major environmental problem is plastics that are discarded into land-fills (about 40%) and accumulation of plastics in the oceans. Recent studies have shown it to be very toxic for aquatic animals - approximately 43% of marine mammal species, 86% of sea-turtle, 44% of sea-birds are susceptible to death due to ingestion of marine plastic debris [5]. Even plastic incineration also generates toxic emissions such as carbon dioxide and methane of GHGs (greenhouse gases) that contribute to worldwide climatic changes. The Intergovernmental Panel on Climate Change (IPCC) trajectory to 2050 for stabilization of atmospheric GHG concentrations at 450 ppm CO2 requires emissions reduction of 80% compared to the 1990 level. This will be perchance the biggest human challenge for the next generation [2].

Nowadays, the government and people are more attentive about the harmful effects of petrochemical derived plastic materials in the environment. Several research works were conducted by scientists for managing plastic waste on earth by finding eco-friendly alternative towards plastic use. Biodegradable plastic will be a convenient alternative to petro-plastic as it is derived from renewable sources such as vegetable oil, corn starch, pea starch or micro biota and it with lower carbon footprint [6]. Biodegradability of bio plastics has been widely publicized in society and the demand for packaging is rapidly increasing among retailers at large scale [4]. The current review will emphasize the need for the community to make perceive the overview of bio plastics and current development.

2. DEGRADABILITY AND BIO PLASTICS

2.1. Degradable plastics

Plastic degradation occurs due to any physical or chemical change in a polymer as a result of Environmental factors, such as light, heat, moisture, chemical conditions or biological activities [7]. Degradable plastics are classified into four types noted in (Figure 1).

The photodegradable bio plastic is made of oil-based polymers and it degradable once exposed to sunlight. It has bonds that are weakened and broken by sunlight or it contains a chemical additive which absorbs light and then attacks the polymer to break. The bio based bio-plastic are produced from a wide range of plant- based raw materials where the resources are modified and processed but which are not necessarily biodegradable. Compostable bio-plastics are biologically decomposed during a composting process at a similar rate [8].

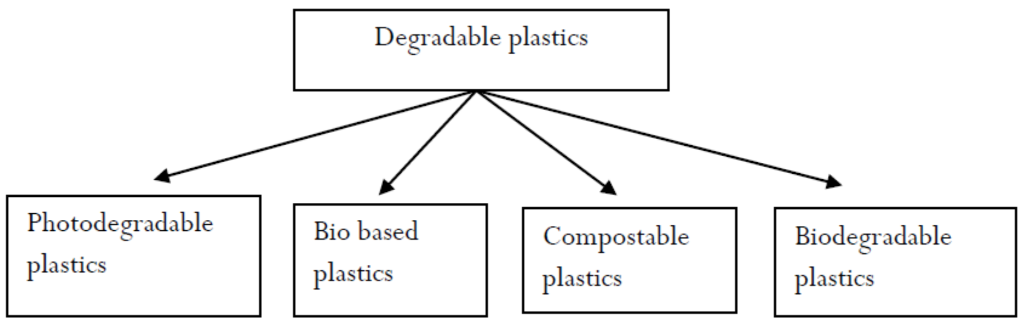

Fig. 1: Types of Degradable plastics

2.2. Biodegradation

It is a biological process in which breaking down of polymer into small particles with the help of microbial activity takes place followed by conversion into methane, water and carbon dioxide. The mechanism of biodegrading the polymer depends upon the thickness and composition of the material [9].

2.3. Biodegradable plastic

A biodegradable plastic is made up of polymers either partly or wholly from polymers derived from biological sources such as sugar cane, potato starch or the cellulose from trees, straw and cotton. Bio plastics can be decomposed after disposal into the environment followed by the activity of microorganisms to produce the final products into carbon dioxide and water without any harmful effects. It supports the earth by offering a reduced carbon footprint, reduced use of fossil resource, reduced plastic waste and the related environmental problems. Bio-plastics are 100% biodegradable, compostable or recyclable [10] noted in figure 2.

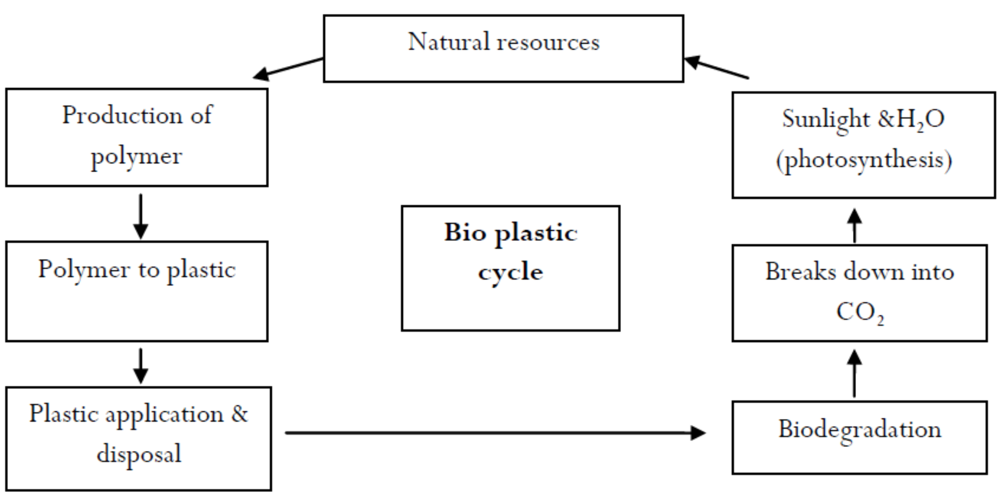

Fig. 2: Bio plastic cycle

The European Bio plastics defines bio plastic as a plastic material if it is either bio based, biodegradable, or features both properties [11]. Different types of biodegradable polymers are being studied for different applications including polyhydroxyalkanoate (PHA), polylactide (PLA), and polyhydroxybutyrates (PHB), cellulose and starch are noted in figure 3.

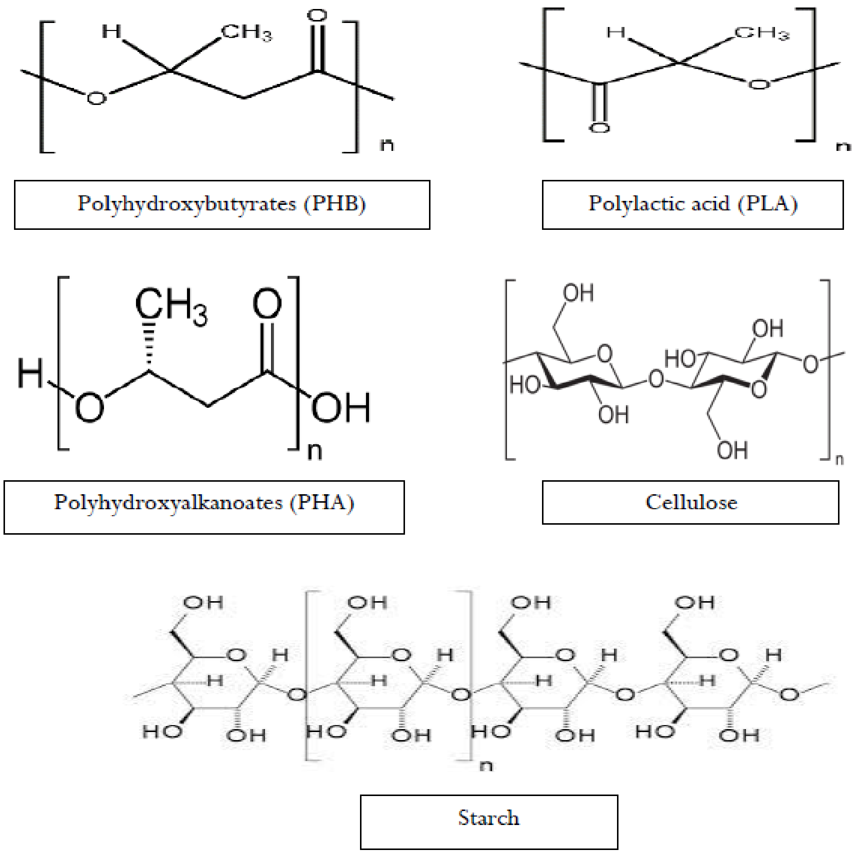

Fig. 3: Chemical structure of polymers

3. PROPERTIES OF BIOPLASTIC

The properties like physical, mechanical and thermal properties are considered with regard to bio plastics. The physical properties considered are mold shrinkage, density and apparent viscosity. The thermal property constitutes melting point, heat distortion temperature and Vicat softening temperature. Mechanical property relates to tensile strength, shrinkage, tensile modulus, tensile elongation brake, compressive yield strength, compressive modulus, flexural strength, Izod impact strength, hardness, bending module, moisture absorption, transparency, oxygen barrier. The other properties like stackability, puncture resistance, crystallinity also consider [12, 13].

4. CARBON CYCLE OF BIO-PLASTICS

The fossil fuels derived plastic disrupts the natural cycle and accelerate the release of carbon dioxide into atmosphere and lead to green house effect. Biogeochemical cycle or Carbon cycle by which carbon is exchanged among the spheres of the earth is an important component which needs to be highlighted. The plants grow by taking in carbon dioxide and when it biodegrades, it releases the carbon dioxide back into the earth. These natural resources undergo different processes to form polymers. Polymers are further processed to bio-plastics. During bio plastic degradation carbon dioxide is released back to the atmosphere. Therefore carbon dioxide which is taken from the environment is cycled back to the atmosphere by passing through different stages and forming a closed cycle. Many bio-plastics are 100% compostable and typically biodegrade in 180 or less days when disposed of in a municipal composting facility and it is absorbed back into the earth as nutrient for the soil. Bio-plastics have two thirds less harmful greenhouse gas emissions and can save up to 35% energy [14].

5. ROLE OF GENETIC ENGINEERING IN BIO PLASTIC

In bio-plastic production, genetically modified microorganisms are used as great source for high yield of bio plastic. It has already been proved to be an efficient bio plastic producer which includes genetically modified bacteria, algae, fungi and plants [15]. For example, Researchers created *Arabidopsis thaliana* plant through genetic engineering that contains enzymes used by bacteria to create plastics [6] .For production of PHA, scientist created genetically modified plants like Switchgrass (*Panicum virgatum*) through genetic engineering. Later, scientists developed genetically modified maize for producing PHA and the plants also being cultivated effectively as a crop of plastic [16] .Biodegradable bio plastic in the form of polyhydroxyalkanoates (PHA) or more specifically polyhydroxybutyrates (PHB) may be produced from genetically engineered Escherichia coli grown on waste carbon sources [17] . Development of high-yielding mutant strains resulted in conversion rates of 65 percent for PHB and eventual PHA yields of 71 percent dry weight [18].

6. COMMERCIALIZED BIOPLASTIC

Some biodegradable plastics commercialized in the market are:

6.1. Starch Based Plastics

The starch is form of polysaccharides and it's abundantly found on earth. Starch based plastics are mostly made from sources of wheat, potatoes, rice, and corn and it could be any plants that higher in starch. Starch based plastics are complex blends of starch with compostable plastics such as PLA, PBAT, PBS, PCL and PHAs [19]. Starch based plastics are used into eating utensils, plates, cups and other products. It account for 80% of the bio plastics market. Starch biodegradable plastics can be processed using conventional technologies such as injection and blow molding, blown film, extrusion and thermo forming [20].

6.2. Microbial based plastic

An additional treatment of microorganism resulted to create a variety of biodegradable plastics. PHA (Polyhydroxy-alkanoates), PHB (Polyhydroxy-butyrates), PLA (Poly lactic acid) is well known synthesised by microbial fermentation.

6.3. PHA plastics

Polyhydroxy-alkanoates (PHA) family of bio-polyesters, are produced by bacterial fermentation of lipids, sugars or by means of chemical substance (chloroform, methylene chloride or propylene chloride) [21]. Bacteria accumulating PHAs is a natural way to store carbon and energy, when nutrient supplies are imbalanced. The greatest number of PHAs is produced by prokaryotic groups such as bacteria and archaeas [22] .To improve their properties, the researchers combine PHA with different monomers by genetic engineering so as to obtain enhanced properties [23] .Diversity has allowed for the development of a variety of applications, including environmentally friendly biodegradable plastics for packaging, fibers and biodegradable implants [24] Eg. *Pseudomonas aeruginosa*, *P.putida,* recombinant *E.coli* [4] .

6.4. PLA plastics

PLA (Poly lactic acid) plastics are derived from the fermentation of byproducts such as starch-rich substances like maize, wheat or sugar and corn starch. The PLA polymer is very attractive for biological and medical applications because it can be spun into filaments that can be used to make textiles or films [10,25] .It approved for direct contact with food and it's applied in food packaging products as it benefit of its high transparency, gloss, stiffness, printability, process ability and excellent aroma barrier [26] .PLA is frequently used in combination with other bio-based and or biodegradable polymers to improve stiffness and strength and to reduce costs [27, 28] .

6.5. Soy Based Plastics

Soybeans are composed of protein with limited fats and oils. The level of protein in soy beans is in the range of 40-55%. This high amount of protein allows the soy to be molded into plastic materials and films. The films produced are commonly used for food coating, as paper pigment structuring agents and flow modifiers. Soy protein plastics can be used in compression and plastic injection molding for production purpose. Soy polymers could offer a very good substitute for non-degradable petroleum-based plastics [29, 30].

6.6. Algal based plastic

Natural polymers extracted from algal biomass include macro algae of sea weeds like alginate, carrageenan, fucoidan, laminarin, agar and ulvan [31, 32]. The use of algae, cyanobacteria (blue green algae) opens up the possibility of utilizing carbon, neutralizing greenhouse gas emissions from factories or power plants [33]. Algae serve as an excellent feedstock for plastic production owing to its advantage of ability to grow in a wide range of environments with high yield. Microalgae feed stocks that are grown on waste streams will provide the lowest cost for a bio refinery system [34]. Bio plastic production using algae that comprise material derived 100% algae are not implemented, only 50% algae were used and for 100% composite material it requires innovative improvement. Commercialization of algae plastic realized many technical problems and it must be overcome. The use of biotechnological techniques can play a key role in conducting the feasibility and sustainability studies in algae bio plastics [23].

6.7. Cellulose Based Plastics

Cellulose is the most abundant biopolymer a form of polysaccharide it exists in variety of species such as animals, plants and bacteria. Cellulose based bio-plastics such as "cellophane film" are biodegradable and are synthesized by some chemical treatment of cellulose xanthate. There are number of types of cellulose fillers such as flax fibre, eucalyptus pulp fibre, hemp fibre and tunicin, have been used as an agent in the bio composite stiffeners [35] .The use of cellulose based plastic is limited in the market because of high production cost.

7. PRODUCTION OF BIOPLASTICS

The prevalent methods of production of bio plastic are:

7.1. From Microorganisms

The prokaryotic cells have storage polymers of polyhydroxyalkanoic acids is well known and widespread indeed. Poly-β-hydroxybutyric acid (PHB) is water insoluble compound and many bacteria produce PHB in large quantities an intracellular carbon and energy storage compound. It was expected that genetically modified organisms may prove to be a very economical and useful synthesis in near future for production of bio plastics [36]. eg. *Pseudomonads* and related species, plant symbiont *Rhizobium* and nitrogenfixing *Azotobacter spp*., Archae including *Haloferax mediterranea* [17].

7.2. From Plants

The plant offers an alternative approach to synthesize bulk commodity products at low cost at major limitation associated with the production of bio plastics by bacteria in high cost. It less expensive as it relies on water, soil and plant production system is much more environment friendly [37] e.g. oil crop such as rapeseed, sunflower and soybean, *Gossypium hirsutum* and *Zea mays* for PHA production [23].

7.3. From food waste

An alternative method is needed when controversy rises regarding the negative impacts of biopolymers, as they contributing global food crisis by using crops as feedstock. The agricultural waste and food industrial wastes accomplished the demand [38]. A waste left from sugar beets during the sugar production consist huge amount of starch, cellulose, hemi cellulose and pectin that can be used to make composite materials from cheap cellulosic material. Extracting pectin from apple pomace waste from cider producing industries with hot aqueous mineral acid that can further isolated from the solution [39, 2]. The used cooking oil like palm oil, sunflower seed, and mixed domestic waste are potential food waste applied in PHA production [40].

Some biodegradable plastic in the market are the following:

7.3.1. Starch-based production of Bio plastics

Starch-based plastics can be prepared in a wide variety of ways. Starch is modified by either plasticization, blending with other materials, genetic or chemical modification or combinations of different approaches in order to improve its mechanical properties .Numerous methods of modification exist include acetylation, oxidation, and acid thinning [20, 28]. Starch works as effective packaging material when it is modified to form films that provide adequate mechanical properties of high percentage elongation, tensile and flexural strength [18].

7.3.2. PHA production

PHAs are produced by many different bacterial cultures. Microroganism include *Cupriavidus necator* (formerly known as *Ralstonia eutropha* or *Alcaligenes eutrophus*) is the one that has been most extensively studied [41]. A few important other microorganism strains that were recently studied include: *Bacillus* sp., *Alcaligenes* sp., *Pseudomonas* spp, *Aeromonas hydrophila*, *Rhodopseudomonas palustris, Escherichia coli, Burkholderia sacchari* and *Halomonas boliviensis.*

The choice of media is important for production of high volumetric final product to economically competitive with conventional plastics. The major cost in production of PHA is the medium and focused on finding cheap media are needed one. Cheap sources for fermentation include contain molasses [42], corn [43], whey [44], wheat and rice bran [45], starch and starchy wastewaters

[46], effluents from olive mill and palm oil mill [47], activated sludge [48], swine waste [49]. The choice of microorganism a wild type or recombinant type also need to be considering on nutrient limiting conditions and polymer of homoplymer or copolymer in the production [50]. There are two stage processes for operating PHAs fermentation. The first stage carried out by production of a high cell density culture followed by second stage a process to increase PHAs concentration. Fermentation conditions depend on the demands of the microbes. A temperature range of 30˚C to 37˚C along with low stirrer speeds, resulting in low dissolved oxygen tension, is adopted. The maintenance of pH is either left to be uncontrolled or is regulated by linking to substrate (*e.g.* glucose) addition [51] .The use of open mixed cultures, such as activated sludge assist in decrease of PHAs cost, thus enhancing their market potential and also increases the efficiency of fermentation [52] .

7.3.3. PHB production

Polyhydroxybutyrates (PHB) are a bio plastic form of polyester of common type of PHA. PHB is produced by bacteria, algae, and genetically modified plants and polymer itself is synthesized directly by the organism [31] .The actual production of the polymer within the cell is a complex enzymatic process. First the production of acetoacetyl-CoA by condensing two molecules of acetyl-CoA together by catalyzes of β-Ketothiolase. Next, acetoacetyl-CoA reductase reduces the acetoacetyl-CoA producing β-hydroxybutyryl-CoA. The final step of PHB synthase to catalyzes the polymerization of of β-hydroxybutyryl-CoA to PHB. The PHB is present as cysts within the cytoplasm of the cell. Therefore, the cell must be destroyed to harvest the PHB [53].

7.3.4. PLA production

Polylactic Acid (PLA) is a thermoplastic made from lactic acid. The conversion of corn or other carbohydrate sources into dextrose followed by fermentation into lactic acid is the way for production. Polylactic acid can be synthesized by number of different ways include direct condensation of the acid free in solution, ring opening polymerization of the ester derivatives of the acid. A recently developed method of synthesizing PLA is via lipase catalysis. The lipase CAL-B at 60°C was found to effectively polymerize lactic acid. This method currently dominates production but the enzymatic approach shows assurance [10, 54].

7.3.5. Cellophane production

Cellophane films are made by cellulose a biodegradable polysaccharide. It can be made by two ways, one way of dissolving it in a mixture of sodium hydroxide and carbon disulphide to obtain cellulose xanthate which is then dipped into a sulphuric acid solution to yield cellophane film [55]. Another way of obtaining cellulose derivatives is the derivatization of cellulose from the solvated state, through the process of esterification or etherification of hydroxyl groups [56] Cellophane processed by laminating, injection or extrusion moulding will exhibit good film forming properties [57].

8. APPLICATION OF BIOPLASTIC

Conventional plastic are non- biodegradable and daily use of that resulted to environmental pollution and keeping in view of problem it promote research and efforts to develop new biodegradable materials that can be applied in manufacturing industry as environmental friendly materials. Biodegradable plastic has been successful implemented in many applications includes:

8.1. Medical industry

The medical industry uses large amounts of one-time use products every day. Plastic gloves and other hygienic products are not recycled and are thrown into landfills. Bio plastics are made out of natural wastes are applied in medical field is very prospective as they as they may tend to cause less allergies as compared to chemical based plastics. These kinds of bio plastics may also find use as the basis for sanitary products like diaper foils, bed under lay, disposable gloves as they are breathable & allow water vapour to permeate, but at the same time waterproof [58].

8.2. Food packaging industry

The food packaging industry makes use of bio plastics in existence. The bio-origin materials obtained through microorganism, starch and cellulose has led to their tremendous innovative uses in food packaging in the last few years [28]. Biodegradable plastic in application of food packaging some important factors needed to be considered as shelf life of product, regulations with respect to food safety. The three most commonly used bio-based plastics with unique properties are PLA, Starch based plastics and Cellophane [59]. Many bio-based plastics have certificates to prove that they will be utilised in food-contact applications. The recently developed bio-based non-biodegradable plastics (bio-PE and bio-PET) are mainly used in food packaging. The increasing awareness of the environmental impact of packaging products drives to development and use of these materials in society [60]. In terms of application, the global biodegradable plastics market is segmented into various applications among them the packaging industry is the largest field which contributes to 60 per cent of global bio plastics production [16].

8.3. Agriculture

Many farmers use blankets of biodegradable plastic made from petroleum to cover their fields and increase their product yield. Biodegradable plastic created from natural resources degrade fully, while current polymers leave residues. Biodegradable mulch film that ploughed into the field once it has been used, offering the opportunity to reduce labour and disposal cost [61].

8.4. Other applications

Textile [62], Automobiles, Electronics, Household, Cosmetics, building and construction [63, 64].

8.5. Application of Starch based plastics

The starch based films are not transparent and it applied in not required of transparency. These materials are suitable for packaging of products like grocery bags. Starch based trays (rigid or foamed) used to pack fruits and vegetables [65]. A specific type of foamed starch tray is Paper foam, mainly used in packaging applications were product protection is important, for example in egg boxes but also in packaging of electronic devices. It also applied in service ware like cups, plates and cutlery, agricultural products (mulching films).

8.6. Applications of PHA

PHAs are non-toxic, biodegradable thermoplastics produced from renewable resources it features of high degree of polymerization, insoluble in water make them highly competitive with polypropylene. It useful in wide range of application particularly in medical oriented. PHAs are used to develop scaffold for tissue engineering [66]. The stereo regular compounds used for biodegradable carriers for long term dosage of drugs, medicines, hormones, insecticides and herbicides [67]. They are also used as osteo synthetic materials in the stimulation of bone growth owing to their piezoelectric properties, in bone plates, surgical sutures and blood vessel replacements [68]. PHA patents cover a good range of PHAs products like coating and packaging, bottles, cosmetic containers, golf tees, and pens. PHAs have cojointly been processed into fibers, for a non-woven fabrics material [69]. PHAs can be used for all sorts of biodegradable packaging materials, including composting bags, food packaging, sanitary articles like diapers and fishing nets, biodegradable rubbers [70].

8.7. Applications of PLA

Poly lactic acid (PLA) is a 100% bio-based plastic that is widely used in packaging applications.

The PLA nowadays have found applications for both short-shelf life products like fresh fruits and vegetables and long shelf life products, like potato chips and pasta [20, 71]. PLA and PLA blends used in the medical industry for make implants, plates, nails, and screws for surgery. It is also expanding to a wide range of fields like textile, cosmetic and household applications and particularly the automobile industries producing the dashboards, door tread plates from the PLA based plastics [63].

8.8. Application of Cellophane

Cellophane films are highly transparent, it be coloured and are well known as candy wrappings. It also used for laminates, flower wrapping, pack products ranging from cheese to coffee and chocolate as it cannot melt and having an excellent dimensional stability [71] .

8.9. Application of soy based plastic

Ford has taken advantage of soy protein plastics and applied it to the plastic components for cars include head restraints, backs and seat cushions. In 2008 Mustang, ford first used soy-based plastic and now all of fords American-built cars have soy-based foam in their head restraints, backs and seat cushions [72].

9. BIODEGRADABILITY TEST

In order to designate a plastic as bio-compostable, its total biodegradability, its disintegration degree, and the possible eco-toxicity of the degraded material must be determined by means of standardized tests. The biodegradation of organic polymers are studied by determining production of Calcium, consumption of oxygen, loss of weight, increase in cell count, and physical examination of sample for evidence of sample destruction [73].

9.1. International Standards

Standards have been developed by American Society for Testing Materials (ASTM) and International Standards Organization (ISO), Deutsches Institut für Normung (DIN), and Japanese Industrial Standards (JIS) for the assessment of the biodegradability of polymers in different environments, such as composting, anaerobic digestion, and wastewater treatment. The parameters includes moisture, combustibles, total nitrogen, pH, un-decompostable ingredients like C:N, Cd, Pb, Hg, As, Cr, Mo, Ni, Cu, Zn [74]. Biodegradability results are strongly based on test conditions of humidity, temperature and microorganisms. Some of the widely used standards are: AS4736; ASTM D5338; ASTM D6002; EN 13432; ISO 14855 (for compost exposure), ASTM D5988; ISO 17556 (for soil exposure); ASTM D6691; ASTM D6692; ISO 15314; and ISO 16221 (for marine exposure) [8,75].

Most importantly, the active microorganism's fungi, bacteria, actinomycetes, etc., must be present at the disposal site. The organism sort determines the suitable degradation temperature, which usually falls between 20 to 60ºC. The disposal site must be rich in oxygen, moisture and mineral nutrients, while the pH must be neutral or slightly acidic (5 to 8) [76]. Fungi is recommended in some of the most important internationally quoted biodegradation test, some are *Pencillium bravicompactum*, *Chaetomium globosum*, *Pencillium cyclopium*, *Aspergillus niger* in ISO R846 1968, AFNOR NF X 41-514 Aout 1961, ASTM D 1924 197, Russian proposal USSR-1 1958 [77].

9.2. Biodegradation of PHAs

PHAs films will degraded upon exposure to soil, compost and marine sediment it biodegradation depend on such as microbial activity of the state, exposed surface area, moisture, temperature, pH and molecular weight of the bio plastics [78]. Biodegradation of PHA under aerobic conditions results in carbon dioxide and water, whereas in anaerobic conditions the degradation products resulted to carbon dioxide and methane. PHAs are compostable over 55% at maximum moisture levels of around 60ºC, 85% of PHA degraded in seven weeks, and over wide range of temperatures [4, 79].

10. RECYCLING OF BIO PLASTICS

There are four different recycling methods - mechanical recycling, chemical recycling, incineration, biological recycling (anaerobic digestion or composting). PLA is one of most studied bio plastics regarding recyclability. The CEN standard for biodegradable polymeric materials stipulates that they must be substantially (>90%) converted to carbon dioxide in a compost environment within six months [80]. The biodegradable plastics which are suitable for anaerobic digestors, thereby bio wastes can be used to drive generators for energy production. Biodegradable plastics entering into municipal waste stream resulted to complicate the recycling process. It makes recycling less economically attractive due to lack of continuous and reliable supply of bio plastic polymer waste is not in amount of large quantity [81].

11. COST OF BIOPLASTIC

Now a day, the cost of production of bio plastic is high as it depends on cost of biomass for fermentation and it production in small scale industrial level. The scale of production has a greater influence on the price than the cost of the raw material source. The cost of bio plastic production will be reduced by production of bio plastic in large scale industrial level and applying technique of blending of substrate with PHB bio plastic [76]. Most bio plastic technology is relatively new and is currently not cost competitive with petro plastic but it will reduce cost advantage over petro plastic in future [6]. In 2020, according to European Bio plastic Association the global production capacity of bio plastic projected to grow four times higher [14].

12. GLOBAL STATISTICS OF BIOPLASTIC

Asia produces around 50 % of bio plastic around the world. Europe has second place in production capacity of bio plastics. New biopolymers like PLA (Poly lactic acid) and PHAs (Polyhydroxyalkanoates) are 100 % bio-based and biodegradable and help the economy of bio based and biodegradable to grow. Approximately 10 % – 15 % bio plastics of the total plastic market will increase its market share to 25%-30% by 2020, and it will be over 10 billion by 2020 [64]. Some global suppliers of starch-based, PHA, PLA and cellulosic plastic products are given in Table 1 [82].

Table 1: Brand name & location of global suppliers of bio plastics

Starch-based plastic	PHA- plastic	PLA- plastic	Cellulosic plastic
Mater-Bi (Italy)	Minerv (Italy)	Biofoam (Netherland)	Natural flex(UK)
Livan (Canada)	Biogreen (Japan)	Ingeo (USA)	Tenite (USA)
Ever Corn (Japan)	Biocycle (Brazil)	Hisun (China)	Biograde (Germany)
Plaststa rch(USA)	Green Bio (China)	Biofront (Japan)	Sateri (China)

13. ADVANTAGES OF BIO PLASTIC

- The bio plastic products are produced from renewable resources and it contributes to reduction of greenhouse gases emission through reduced carbon foot print [83, 84].
- The production of bio plastics also consumes 65% less energy than the production of petrochemical plastics. The Bio plastics would be recycled and utilized for energy recovery [85, 86].
- The bio plastics can evade the environmental problems like uncontrolled dumping of wastes on land and disposal to sea, and the related emission of toxic substances. However, effective implementations of collection, sorting and recycling practices and public awareness are also required to premium the assets of bio plastics [87].
- It benefits the rural economy, in the production of bio-fuels and bio-plastics, as countries across the world look for alternatives to oil to safeguard the environment and for attaining energy security [14].
- Bio plastic from plant resources can manage the plant waste or plant residues in an efficient manner [84].

14. DISADVANTAGES OF BIO PLASTIC

- The manufacturing cost of bio plastics is higher than conventional plastic. When the amount of large-scale industrial production of bio plastics implemented more common in the future, the cost reduction will expected [8].
- The packaging materials of starch and cellulose based plastic gives poor process ability, brittleness, vulnerability to degradation, limited long-term stability and poor mechanical properties due to their hydrophilic nature [56].
- A problem of contamination by recycling process of bio plastic material if not separated from conventional plastics [14].
- Raw material reserves might reduce by bio plastics production [88].

15. CURRENT RESEARCH AND DEVELOPMENT

Studies of biodegradable plastic have become very popular over the years because of its low density, availability in abundance and easy process ability. Moreover it's important for the global community to have an alternative for the product derived from petroleum oil such as plastics.

- The advancement of genetic engineering has produced genetically modified microorganism and plants that may significantly improve yields and production capabilities while reducing overall costs of bio plastic. The several strains of microalgae have been studied at the genetic level and currently being sequenced that will promote different possible bio plastic products [34].
- In recently (2004-2011) various biodegradable plastic companies like Synbra technology, fujitsu technology make use of bio plastic in their manufacturing [6].
- Grafting an important technique developed for modifying the physical and chemical properties of polymers. Starch grafted on vinyl emulsion also undergoes biodegradation and can be used as sustainable packaging material [89].
- Various natural fibres such as flax, hemp, bamboo, pineapple, kenaf, henequen and hemp have been studied as reinforcing agent for the polymer matrix by different researchers [90].
- In 2001, BASF introduced Eco-flex is a fully biodegradable plastic material. The material is resistant to water, grease, hygienic for disposable wrapping, decomposes in normal composting systems. Consequently, Eco-flex has found a number of suitable applications as a packaging wrap [76].

16. CONCULSION

Bio plastic plays a significant part in the innovation to current world to control pollution by plastic waste as it would offer sustainable and eco-friendly alternative one. The problems like recycling, dumping, longevity period for degradation of plastic waste will be overcome by biodegradable plastics. Commercial production of bio-plastic may be costly currently but in future with more technological improvement like use of genetically modified organism may result in great and feasible endeavour. The more intensified research is needed for large-scale production and commercialization of bio plastic products to successful in world wide.

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